



**UNIVERSITI PUTRA MALAYSIA**

**VERTICAL FAST HANDOFF TECHNIQUE FOR MOBILE IPv6 IN  
HETEROGENEOUS 4G NETWORKS**

**VAHID SOLOUK**

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**VERTICAL FAST HANDOFF TECHNIQUE FOR MOBILE IPv6 IN  
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**By**

**VAHID SOLOUK**

**Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia,  
in Fulfilment of the Requirement for the Degree of Doctor of Philosophy**

**August 2009**



## DEDICATION

***To my dearest family,***

***...for their unconditional and everlasting love and support***

***To my kindest wife, Ayda, and my sweetest son, Ilkin***

***...in all love, humility, and gratitude***

**Abstract of thesis presented to the Senate of Universiti Putra Malaysia in  
fulfilment of the requirement for the degree of Doctor of Philosophy**

**VERTICAL FAST HANDOFF TECHNIQUE FOR MOBILE IPv6 IN  
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**By  
VAHID SOLOUK  
August 2009**

**Chairman: Professor Borhanuddin Mohd Ali, PhD  
Faculty: Engineering**

Over the recent years, mobility in wireless communications has become a big interest of communication and network researches due to the rising demand on and expectations of wireless Internet access. However, since none of the existing wireless technologies can individually fulfill all the tasks arising from the Internet users' demands, the integration or coexistence of different communication systems having different network characteristics is inevitable. This integration on the other hand, requires seamless inter-system mobility solutions. Every inter-system roaming which leads to vertical handoff requires proper interaction of both link and IP layers, since network point of attachment as well as the device interface are involved in handoff. Many investigations in

standardization are being made to finally design and implement each of these communication layers. This thesis details out the whole research, which is done in two main components. As for the first component, a link layer mechanism with the notion of a selection algorithm based on weighted mean is primarily introduced for collecting link layer information and discovering the candidate access router. This mechanism is then used as handoff decision phase with an improved mobile-assisted handoff method as an extension of Fast Mobile IPv6 Handoff (FMIPv6) in vertical mode. The performance of the proposed methods is discussed using analysis and comparison of simulation results with well-known methods in the field. The method has been shown to achieve performance improvements in terms of higher preference level of selection for various cases, and in terms of latency and packet loss, by 45% and 83% respectively, while maintaining comparatively lower buffer sizes. As the second component, a framework is proposed to incorporate an integration mode of cellular and wireless networks called semi tightly-coupled. This framework is further used to design and implement an end-to-end roaming solution as Vertical Fast Handoff (VFHO) for the integrated network. The performance of the proposed framework has been analyzed mathematically and through simulations which show the robustness of VFHO in terms of signaling cost, end-to-end packet delivery cost, overall handoff latency, and packet loss based on various system variables. Under several simulations, the number of lost packets encountered by VFHO stayed as low as 20 packets when the arrival rate was a

maximum of 50 packets per second, and did not exceed 10 packets in the case when packet sizes was at a maximum of 256 Bytes or when buffer size was set to 50 KB. Besides, the delay varied between 200 and 600 ms in cases when the Duplicate Address Detection (DAD) and wireless link delays reached up to 600 ms and 70 ms, respectively. In conclusion, the selection-based decision mechanism in vertical handoff such as VFHO, can be good for congestion control, and achieve long-term objectives such as load sharing.

**Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia  
sebagai memenuhi keperluan untuk ijazah Doktor Falsafa**

**TEKNIK PENYERAHAN PANTAS MENEGAK UNTUK IPV6 BERGERAK  
DALAM RANGKAIAN PELBAGAI JENIS 4G**

**Oleh  
VAHID SOLOUK  
Ogos 2009**

**Pengerusi: Profesor Borhanuddin Mohd Ali, PhD  
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Semenjak kebelakangan ini, kebolehgerakan dalam komunikasi tanpa wayar telah menarik minat dalam penyelidikan komunikasi dan rangkaian; ini adalah disebabkan permintaan dan harapan yang meningkat dari pencapaian tanpa wayar berinternet. Walau bagaimanapun, oleh kerana tiada satu pun di antara teknologi tersebut mampu dengan sendirinya untuk memenuhi kesemua tugas yang lahir dari permintaan pengguna Internet, penggabungan atau kewujudan bersama di kalangan sistem sistem komunikasi yang pelbagai yang mempunyai pelbagai ciri rangkaian, adalah tidak dapat dielakkan. Sebaliknya, pengintegrasian memerlukan penyelesaian pergerakan antara-sistem yang tak berklm. Setiap perayauan antara-sistem yang menjurus kepada penyerahan

menegak memerlukan interaksi yang sempurna untuk kedua dua lapisan pautan dan IP, oleh kerana titik penyambungan rangkaian dan juga pengantaramuka peranti adalah terlibat dalam penyerahan. Beberapa banyak kajian dalam piawaian sedang dibuat untuk akhirnya merekabentuk dan melaksanakan setiap lapisan komunikasi ini. Tesis ini mendetilkan keseluruhan penyelidikan ini, dan ia dilakukan dalam dua komponen utama. Untuk komponen pertama, suatu mekanisme lapisan pautan dengan tanggapan satu algoritma pemilihan berasaskan min pemberat adalah diperkenalkan untuk memungut maklumat lapisan pautan dan menemui penhala capaian calon. Mekanisme ini kemudian digunakan sebagai fasa keputusan penyerahan dengan kaedah penyerahan telefon bimbit-dibantu sebagai tambahan kepada Penyerahan Telefon-bergerak IPv6 Pantas (FMIPv6). Prestasi kaedah kaedah cadangan adalah dibincangkan menggunakan analisis dan bandingan hasil keputusan simulasi dengan kaedah yang terkenal dalam bidang ini. Kaedah ini telah menunjukkan bahawa ia telah mencapai penambahbaikan prestasi dalam bentuk pemilihan yang mempunyai tahap keutamaan yang lebih tinggi untuk beberap kes, dan dalam bentuk lengah dan kehilangan paket, dengan 45% dan 83% masing masing, sambil mengekalkan saiz penimbal yang lebih kecil. Sebagai komponen kedua, satu kerangka adalah dicadangkan untuk memasukkan model integrasi rangkaian bersel dan tanpa wayer dinamakan gabungan-ketat separa. Kerangka ini seterusnya digunakan untuk mereka dan melaksanakan satu penyelesaian perantauan hujung-ke-hujung sebagai



Penyerahan Pantas Menegak untuk rangkaian bergabung. Prestasi kerangka yang dicadangkan ini telah dianalisis secara matematik dan melalui simulasi yang menunjukkan ketahanan VFHO dalam bentuk kos pengisyaratan, kos penghantaran paket hujung-ke-hujung, lengah serahan menyeluruh, dan kehilangan paket berdasarkan beberapa pembolehubah sistem. Dalam beberapa simulasi, bilangan paket hilang yang dihadapi oleh VFHO tetap rendah sehingga 20 paket apabila kadar ketibaan adalah pada maksimum 50 paket sesaat, dan tidak melebihi 10 paket dalam kes di mana saiz paket adalah pada peringkat maksimum 256 Bait atau saiz penimbal disetkan kepada 50KB. Selain dari itu, lengahnya berubah ubah di antara 200 dan 600ms dalam kes di mana Pengesanan Alamat Pendua (Duplicate Address Detection (DAD)) dan lengah pautan tanpa wayer mencapai sehingga 600ms dan 70ms, masing masing. Sebagai penutup, mekanisme keputusan berasaskan pemilihan dalam serahan menegak seperti VFHO, adalah baik untuk kawalan kesesakan, dan mencapai objektif jangka-panjang seperti perkongsian beban.

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## **APPROVAL**

I certify that a Thesis Examination Committee has met on August 27, 2009 to conduct the final examination of Vahid Solouk on his thesis entitled “Vertical Fast Handoff Technique for Mobile IPv6 in Heterogeneous 4G Networks” in accordance with the universities and university colleges Act 1971 and the constitution of the Universiti Putra Malaysia [P.U. (A) 106] March 15, 1998. The Committee recommends that the candidate be awarded the Doctor of Philosophy.

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Date: 15 October 2009



## **APPROVAL**

Saya mengesahkan bahawa satu Jawatankuasa Peperiksaan Tesis telah berjumpa pada 28 Ogos 2009 untuk menjalankan peperiksaan akhir bagi Vahid Solouk bagi menilai tesis beliau yang bertajuk “Teknik Penyerahan Pantas Menegak Untuk Ipv6 Bergerak Dalam Rangkaian Pelbagai Jenis 4G” mengikut Akta Universiti dan Kolej Universiti 1971 dan Perlembagaan Universiti Putra Malaysia [P.U.(A) 106] 15 Mac 1998. Jawatankuasa tersebut telah memperakukan bahawa calon ini layak dianugerahi ijazah Doktor Falsafa.

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**Date: 16 November 2009**



## **DECLARATION**

**I hereby declare that the thesis is based on my original work except for quotations and citations, which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.**

---

**VAHID SOLOUK**

**Date:**

## TABLE OF CONTENTS

	Page
ABSTRACT	iii
ABSTRAK	vi
ACKNOWLEDGMENT	ix
APROVAL	x
APROVAL	xi
DECLARATION	xiii
LIST OF TABLES	xviii
LIST OF FIGURES	xix
LIST OF ABBREVIATIONS	xxi
1 INTRODUCTION	1
1.1 Preface	1
1.2 Background and Motivation	2
1.3 Statement of Problem and Hypotheses	6
1.3.1 Problem 1	6
1.3.2 Problem 2	7
1.4 Aims and Objectives	8
1.5 Main Assumptions and Scope of Study	9
1.6 Areas of Study	10
1.7 Outline of Thesis	11
2 BACKGROUND AND REVIEW OF RELATED LITERATURE	13
2.1 Heterogeneous Wireless Networks, Infrastructure and Components	13
2.1.1 IEEE802.11 WLAN Standards	15
2.1.2 Universal Mobile Telecommunications System (UMTS)	21
2.1.3 Integration of WLAN and 3G	24
2.2 Vertical Handoff	28
2.3 Network Discovery and Selection	29
2.3.1 Access Router Discovery	30
2.3.2 Selection Criteria	31
2.3.3 Selection Policy	32
2.4 IEEE802.21 Media Independent Handover	36
2.5 MIPv6 and FMIPv6	40



2.5.1	Hierarchical Mobile IPv6 (HMIPv6) and FHIPv6	43
2.6	Summary	45
<b>3</b>	<b>IMPROVED ACCESS ROUTER DISCOVERY (IARD)</b>	<b>46</b>
3.1	Introduction	46
3.2	Motivations and Related Works	49
3.3	Considerations of Network Discovery and Selection	52
3.4	Protocol Description	53
3.4.1	Initializing the Registration Entries	54
3.4.2	Acquiring Information and Entry Completion	55
3.4.3	Identifying the Potential ARs	56
3.4.4	Nomination Algorithm	56
3.4.5	Determining “AR Type” Values	60
3.4.6	Determining Weights	61
3.4.7	Information Delivery to MN	63
3.5	Clarification of Criteria Sufficiency	64
3.6	Considerations for RSS	65
3.7	Modeling and Implementation	68
3.7.1	Central Location Register Process Model	69
3.8	Simulation Results and Analyses	72
3.8.1	Scenario 1: Presence of Five Neighboring WLAN Access Routers	73
3.8.2	Analysis of the Results	80
3.8.3	Scenario 2: Heterogeneous Network with Five Different ARs	83
3.9	Summary	95
<b>4</b>	<b>IMPROVED FMIPv6 USING IARD</b>	<b>97</b>
4.1	Introduction	97
4.2	Motivation and Hypotheses	98
4.3	FMIPv6 vs. Link Layer Handoff	100
4.3.1	Issues with Layer 3 Mobility using FMIPv6	101
4.3.2	Framework of IEEE802.21	103
4.3.3	Integration of IEEE802.21 and FMIPv6	104
4.4	Considerations for FMIPv6 in Heterogeneous Environments	106
4.4.1	Contributions	107
4.4.2	New Messages and Primitives	108
4.5	Protocol Description	108
4.5.1	Handoff Decision Phase	111
4.5.2	Handoff Preparation	111
4.5.3	Handoff Execution and Packet Forwarding	112
4.5.4	Handoff Completion and Packet delivery	113
4.6	Delay Analysis and Discussions	115
4.6.1	Definition of Handoff Latency	115
4.6.2	Delay Calculation in FMIPv6	116
4.7	Simulation Results and Further Discussions	123
4.7.1	Simulation Scenario and Assumptions	123
4.7.2	Numerical Results and Discussions	126
4.8	Summary	133



<b>5</b>	<b>VERTICAL FAST HANDOFF (VFHO)</b>	<b>135</b>
5.1	Introduction	135
5.1.1	Motivation and Challenges	136
5.2	Related Works	137
5.3	Contribution	139
5.4	Design and Assumptions	141
5.4.1	Serving Area Division	141
5.4.2	Handoff Decision Engine (HDE)	143
5.4.3	Handoff Information Register (HIR)	144
5.4.4	AR Selection in HIRs	144
5.4.5	Selection Algorithm using Weight Function	145
5.5	Protocol Overview	151
5.5.1	Handoff Decision and Preparation	153
5.5.2	Target Network Selection	154
5.5.3	Handoff Preparation	154
5.5.4	Early Binding Update with CN	155
5.5.5	Link Activation and IP Layer Handoff	156
5.5.6	Packet Delivery	157
5.6	Numerical Analyses	158
5.6.1	Analytical Model	158
5.6.2	Handoff Latency	158
5.6.3	Packet Delivery	161
5.6.4	Signaling Cost	165
5.7	Simulation Parameters and Assumptions	172
5.7.1	UMTS System Definition and Assumptions	172
5.7.2	Domain and Switching Types	173
5.7.3	WLAN System Specifications and Assumptions:	174
5.7.4	Specifications of UMTS-WLAN Integration	175
5.7.5	Serving Area Management	176
5.7.6	Simulation Parameters	177
5.8	Simulation Design and Implementation	178
5.8.1	Vertical Fast Handoff Model	179
5.8.2	Dual-Faced Mobile Node	181
5.8.3	Design of HIR-M and CLR Entities	188
5.9	Simulation Results and Discussions	189
5.9.1	Handoff Latency	190
5.9.2	Packet Loss	195
5.9.3	Packet Delivery Delay	200
5.10	Summary	200
<b>6</b>	<b>SUMMARY, GENERAL CONCLUSION AND FUTURE DIRECTIONS</b>	<b>202</b>
6.1	Summary and Conclusions	202
6.2	Contributions	204
6.2.1	Network Discovery and Selection Method in Heterogeneous Network	205
6.2.2	Improved Handoff Decision and Execution using FMIPv6	205
6.2.3	A Semi tightly-coupled Framework for UMTS-WLAN Integration	206
6.2.4	An End-to-End Mobile Controlled Fast Handoff Method	206

6.3 Future Directions	207
REFERENCES	209
BIODATA of Student	222
LIST OF PUBLICATIONS	223

## LIST OF TABLES

Table	Page
2.1. Specifications of IEEE802.11 WLAN Standards	16
2.2. Comparison of 3G-WLAN Integration Approaches	25
3.1. The AR Records Registered in CLR	73
3.2. Specifications of WLAN Standards	74
3.3. Weighted Mean vs. Weighted Sum for Case 1	77
3.4. Weighted Mean vs. Weighted Sum for Case 2	78
3.5. Weighted Mean vs. Weighted Sum for Case 3	79
3.6. Weighted Mean vs. Weighted Sum for Case 4	80
3.7. AR Records Reported	84
3.8. Criterion Rank Based on Traffic Profile	86
3.9. Numerical Results of Weighted Mean and TOPSIS for Three Traffic Classes	88
4.1. New Message and Primitive Structure	108
4.2. System Parameters	126
5.1. New Message and Primitive Structure for VFHO	140
5.2. Collected Network Characteristics as Selection Criteria	147
5.3. Fixed Parameters for Analytical Model	169
5.4. Simulation Parameters for Area Coverage and UMTS-WLAN	177
5.5. Simulation Variables for VFHO Delay and Loss	189



## LIST OF FIGURES

Figure	Page
1.1.The Study Approach Followed	11
2.1. A Typical Heterogeneous Wireless Network Coverage Area	15
2.2. IEEE802.11 Architecture, a) Infrastructure Mode with Coexistence of BSS and ESS, b) Ad-Hoc Mode	17
2.3. Establishing Association in IEEE802.11x	20
2.4. 3GPP Recommendations for UMTS Implementation (Release 8)	23
2.5. WLAN-3G Integration Schemes	27
2.6. MIHF Shim Layer Interconnection	38
2.7. Handoff Procedure in Predictive FMIPv6	42
2.8. HMIPv6 Network with Two Domains	44
3.1. Message Diagram for IARD Router Discovery Method	54
3.2. Flowchart Diagram of IARD	66
3.3. Process Model for CLR Module	71
3.4. Simulation Results of Scenario 1, Weighted Sum vs. Weighted Mean for Different Traffic Classes	81
3.5. Results for Weighted Mean for Scenario 2, Case 1, IARD Nomination for Different Traffic Classes	87
3.6. Weighted Mean vs. TOPSIS for Voice Services	89
3.7: Weighted Mean vs. TOPSIS for Streaming Services	89
3.8: Weighted Mean vs. TOPSIS for Interactive Services	90
3.9: Impact of Service Improvement of AR5 in Total Ranking	93
3.10. Impact of Packet Errors in AR5 Showing a Drop of Ranking	94
4.1. Handoff Procedure in Predictive FMIPv6	102
4.2. Improved FMIPv6 (IFMIP) with IARD	110
4.3. Vertical Handoff Scenario with MN Approaching the Neighborhood of WLANs	125
4.4. Buffering Requirements	128
4.5. Overall Handoff Latency of the Protocols for Medium and Heavy Loads vs. MN Speed	129

<b>4.6. Packet Loss per MN Speed</b>	<b>131</b>
<b>4.7: Packet Loss for Both Handoff Methods</b>	<b>131</b>
<b>5.1. Semi Tightly-Coupled Integration with Defined Coverage Areas</b>	<b>143</b>
<b>5.2. Message Flow Diagram of VFHO</b>	<b>152</b>
<b>5.3. Timing Diagram for Transmissions and Processes of VFHO</b>	<b>159</b>
<b>5.4. a) VFHO Latency vs. Wireless Delay for Various MN Speeds, b) Packet Delivery vs. Arrival Rate for Various <math>\phi</math></b>	<b>164</b>
<b>5.5. Total Signaling Cost Variations vs. a) Number of LAs, b) MN Density, c) SMR, and d) RA Size</b>	<b>170</b>
<b>5.6. Simulation Network Topology and Scenario</b>	<b>179</b>
<b>5.7. Node Model for Dual-Faced Mobile Node</b>	<b>180</b>
<b>5.8. Process Model for MAC Unifier module</b>	<b>183</b>
<b>5.9. Common Process Model for HIR Modules</b>	<b>187</b>
<b>5.10. Process Model for HDE</b>	<b>187</b>
<b>5.11. Handoff Delay vs. a) Wireless Link Delay, b) Node Speed for Various DAD and BI Values</b>	<b>194</b>
<b>5.12. Packet Loss vs. Packet Arrival Rate (<math>\lambda_p</math>) for Various DAD Values</b>	<b>196</b>
<b>5.13. Packet Loss vs. Packet Size for Various Packet Arrival Rates</b>	<b>198</b>
<b>5.14. Packet Loss vs. Buffer Size for Various Packet Arrival Rates</b>	<b>199</b>

## LIST OF ABBREVIATIONS

<b>3G</b>	<b>Third Generations of wireless systems</b>
<b>3GPP</b>	<b>Third Generation Partnership Project</b>
<b>4G</b>	<b>Fourth Generations of wireless systems</b>
<b>AHP</b>	<b>Analytic Hierarchy Process</b>
<b>AP</b>	<b>Access Point</b>
<b>AR</b>	<b>Access Router</b>
<b>ARD</b>	<b>Access Router Discovery</b>
<b>B3G</b>	<b>Beyond 3G wireless systems</b>
<b>BS</b>	<b>Base Station</b>
<b>BSS</b>	<b>Basic Service Set</b>
<b>BU/BA</b>	<b>Binding Update &amp; Acknowledgement</b>
<b>cAR</b>	<b>candidate Access Router</b>
<b>CARD</b>	<b>Candidate Access Router Discovery</b>
<b>CLR</b>	<b>Central Location Register</b>
<b>CN</b>	<b>Correspondent Node</b>
<b>CoA</b>	<b>Care-of-Address</b>
<b>CRC</b>	<b>Cyclic Redundancy Check</b>
<b>CS</b>	<b>Circuit Switched</b>
<b>CSMA/CA</b>	<b>Carrier Sense Media Access with Collision Avoidance</b>
<b>CTS</b>	<b>Clear to Send</b>
<b>DAD</b>	<b>Duplicate Address Detection</b>
<b>DCF</b>	<b>Distributed Coordination Function</b>
<b>DS</b>	<b>Distribution System</b>
<b>ESS</b>	<b>Extended Service Set</b>
<b>FBU/FBAck</b>	<b>Fast Binding Update &amp; Acknowledgement</b>
<b>FHMIPv6</b>	<b>Fast Handover for Hierarchical Mobile IPv6</b>
<b>FMIPv6</b>	<b>Fast Handover for MIPv6</b>
<b>GERAN</b>	<b>GSM EDGE Radio Access Network</b>
<b>GGSN</b>	<b>Gateway GPRS Support Node</b>
<b>GPRS</b>	<b>General Packet Radio System</b>
<b>GRA</b>	<b>Grey Relational Analysis</b>
<b>GSM</b>	<b>Global System for Mobile Communications</b>
<b>HA</b>	<b>Home Agent</b>
<b>HDE</b>	<b>Handoff Decision Engine</b>
<b>HI/HAck</b>	<b>Handoff Initiation &amp; Acknowledgement</b>
<b>HIR</b>	<b>Handoff Information Register</b>
<b>HMIPv6</b>	<b>Hierarchical Mobile IPv6</b>
<b>HoA</b>	<b>Home-of-Address</b>
<b>HSDPA</b>	<b>High Speed Downlink Packet Access</b>
<b>IARD</b>	<b>Improved Access Router Discovery</b>

<b>IBSS</b>	<b>Independent Basic Service Set</b>
<b>ICMP</b>	<b>Internet Control Message Protocol</b>
<b>IEEE</b>	<b>Institute of Electrical and Electronic Engineering</b>
<b>IETF</b>	<b>Internet Engineering Task Force</b>
<b>FMIP</b>	<b>Improved FMIPv6</b>
<b>IMS</b>	<b>IP Multimedia System</b>
<b>ISM</b>	<b>Frequency band for Industrial, Scientific, Medical purposes</b>
<b>IWU</b>	<b>Interworking Unit</b>
<b>LA</b>	<b>Link Available</b>
<b>LAR</b>	<b>Local Area Report</b>
<b>LBU</b>	<b>Local Binding Update</b>
<b>LCR</b>	<b>Link Change Report</b>
<b>LR</b>	<b>Link Ready</b>
<b>LRR</b>	<b>Local Registration Request</b>
<b>LUQ</b>	<b>Local Update Query</b>
<b>LUR</b>	<b>Local Update Request</b>
<b>MAC</b>	<b>Media Access Control</b>
<b>MGW</b>	<b>Media Gateway</b>
<b>MICS</b>	<b>Media Independent Command Service</b>
<b>MIES</b>	<b>Media Independent Event Services</b>
<b>MIH</b>	<b>Media Independent Handover</b>
<b>MIHF</b>	<b>Media Independent Handover Function</b>
<b>MIIS</b>	<b>Media Independent Information Service</b>
<b>Mipshop</b>	<b>Mobility for IP, services, handover, performance</b>
<b>MIPv6</b>	<b>Mobile Internet Protocol version 6</b>
<b>MN</b>	<b>Mobile Node</b>
<b>nAR</b>	<b>new Access Router</b>
<b>nCoA</b>	<b>new Care-of-Address</b>
<b>NS/NA</b>	<b>Neighbor Solicitation &amp; Advertisement</b>
<b>pAR</b>	<b>previous Access Router</b>
<b>PCF</b>	<b>Point Coordination Function</b>
<b>PDA</b>	<b>Personal Digital Assistant</b>
<b>PDN</b>	<b>Packet Data Network</b>
<b>PHY</b>	<b>Physical Layer</b>
<b>PrRtAdv</b>	<b>Proxy Router Advertisement</b>
<b>PS</b>	<b>Packet Switched</b>
<b>QoS</b>	<b>Quality of Service</b>
<b>RAN</b>	<b>Radio Access Network</b>
<b>RBU</b>	<b>Remote Binding Update</b>
<b>RF</b>	<b>Radio Frequency</b>
<b>RNC</b>	<b>Radio Network Control</b>
<b>RO</b>	<b>Route Optimization</b>
<b>RSS</b>	<b>Received Signal Strength</b>

<b>RTS</b>	<b>Request to Send</b>
<b>RtSolPr</b>	<b>Router Advertisement for Proxy</b>
<b>SAP</b>	<b>Service Access Point</b>
<b>SAW</b>	<b>Simple Additive Weighting</b>
<b>SCTP</b>	<b>Stream Control Transmission Protocol</b>
<b>SGSN</b>	<b>Serving GPRS Support Node</b>
<b>SIP</b>	<b>Session Initiation Protocol</b>
<b>TOPSIS</b>	<b>Technique for Order Preference by Similarity to Ideal</b>
<b>Solution</b>	
<b>UMTS</b>	<b>Universal Mobile Telecommunication System</b>
<b>UNA</b>	<b>Unsolicited Neighbor Advertisement</b>
<b>UTRAN</b>	<b>UMTS Terrestrial Radio Access Network</b>
<b>VFHO</b>	<b>Vertical Fast Handoff</b>
<b>WCDMA</b>	<b>Wideband Code Division Multiple Access</b>
<b>WLAN</b>	<b>Wireless Local Area Network</b>
<b>WMAN</b>	<b>Wireless Metropolitan Area Network</b>
<b>WPAN</b>	<b>Wireless Personal Area Network</b>
<b>WWAN</b>	<b>Wireless Wide Area Network</b>



## TERMINOLOGY

**Potential AR:** Refers to all available ARs in the neighborhood of the AR reported by MN. Potential ARs are identified based on their local area ID (LAID).

**Nominated AR:** Each AR with the top three value of  $M_W$  is shortlisted and named as nominated AR.

**Prospective AR:** Any AR that is detected by the MN and reported to the previous Access Router (pAR) is called prospective AR.

**Candidate AR:** The AR that is selected from the list of nominee ARs as the MN's next point of attachment.

**Case:** During each phase of experiments, the protocols are studied in the presence of each traffic class as a separate case.

**Scenario:** As defined in the context, a scenario is referred to a phase of experiments where various cases with similar system parameters are investigated.

**Distinguishing level:** Defined as the difference between the best and the worst values of weighted mean ( $M_W$ ) obtained for each AR.